Downwind of the Flames:

Assessing and Predicting Wildfire Smoke Related Morbidity Using Satellites, In-Situ Measurements and Models

Jeff Pierce

Sheryl Magzamen, Emily Fischer, John Volckens, Gabriele Pfister

Bonne Ford, Ryan Gan, Will Lassman, Katelyn O'Dell, Maryssa Loer

Colorado State University

Project Overview

Objectives:

1: Estimate the respiratory and cardiovascular health risks for specific demographic populations exposed to wildfire PM.

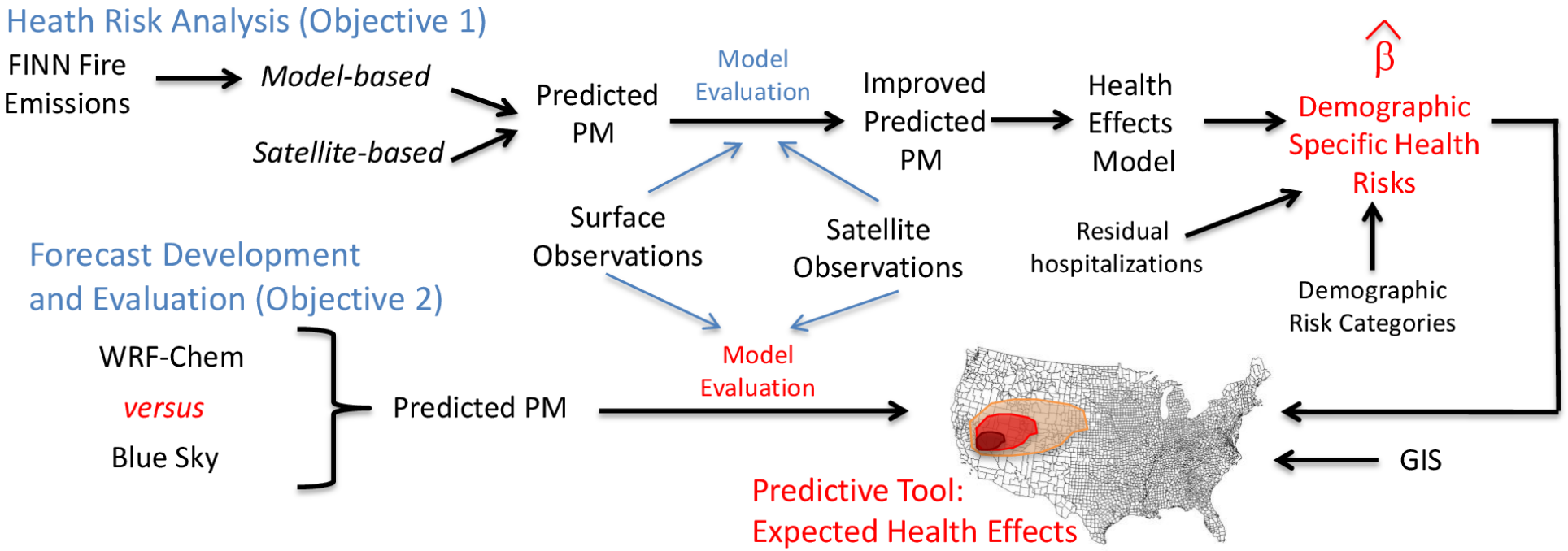
2: Evaluate and develop forecast tools that predict wildfire PM concentrations, population exposure and the potential increased morbidity due to wildfire smoke.

Team:

CSU Atmospheric Science: Jeff Pierce, Emily Fischer, Bonne Ford, Will Lassman, Katelyn O'Dell*
CSU Mechanical Engineering: John Volckens
CSU Environmental Health: Sheryl Magzamen, Ryan Gan
NCAR: Gabriele Pfister

* *New Student Hired for Project in 2016*

Project Overview



Objective 1: Health-risk analysis

Analyze past fires

	Time Period	Location (s) of Fires	Most Intense Smoke Impact Regions	Estimated population impact	Notes
	8/17/13 – 10/24/13	Rim Fire near Yosemite	Northern California, Nevada	320,000	Reno and Sparks, NV reached >90 μg m^{-3} $PM_{2.5}$
✓	8/8/13 – 8/20/13	Central Idaho	Idaho extending to downwind states to the south.	260,000	Unhealthy levels of PM impacted Boise and Twin Falls, ID
	7/26/13 – 9/4/13	Douglas Complex Fires Western Oregon	Southwestern Oregon and Northern California	76,000	Medford, OR reached Very Unhealthy Levels of $PM_{2.5}$
✓	9/8/12 – 9/29/12	Washington Fires	Washington, Oregon, Idaho	33,000	Wenatchee, WA $PM_{2.5}$ was sustained above 400 μg m^{-3} for several days.
✓	8/12/12 – 9/15/12	Northern California	Northern California and Central Oregon	21,000	$PM_{2.5}$ exceeded 150 μg m^{-3} $PM_{2.5}$
✓	8/8/12 – 9/15/12	Idaho	Idaho, Montana, and Wyoming	3,100	ID/MT boarder reached 150 μg m^{-3} $PM_{2.5}$.
✓	6/9/12- 6/30/12	High-Park Fire	Northern Colorado	150,000	Fort Collins, CO reached over 200 μg m^{-3} $PM_{2.5}$
	6/1/11 – 7/1/11	Eastern Arizona, New Mexico	Arizona, New Mexico, Texas Oklahoma	8,900	$PM_{2.5}$ was extremely elevated in regions of AZ and NM
	9/6/10 – 9/16/10	Four Mile Canyon Fire, Boulder, CO	Boulder, Denver, Fort Collins, and Colorado Springs, CO	1.32 mil	Hourly $PM_{2.5}$ exceeded 150 μg m^{-3} over a several day period
✓	8/26/09 – 9/6/09	Southern CA	Los Angeles County, CO	10.02 mil	Hourly $PM_{2.5}$ exceeded 100 μg m^{-3} in downtown LA
	6/22/08 – 9/15/08	Northern California	Sacramento and Chico, CA	550,000	Elevated $PM_{2.5}$ in NV, OR, ID, UT, and CO for ~two months.
Population estimates were derived from US Census Bureau, State & County Quickfacts: 2012 estimates were used for episodes including and after 2012; 2010 estimates were used for all other case studies.					

✚ Canadian and Washington Fires Summer 2015

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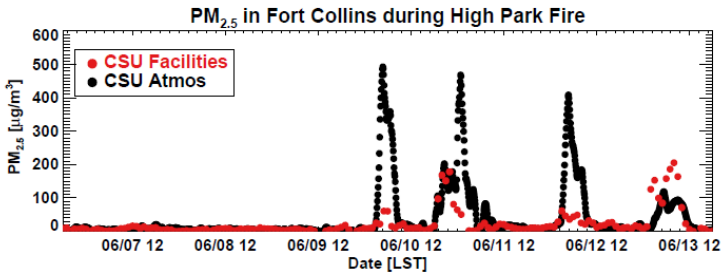
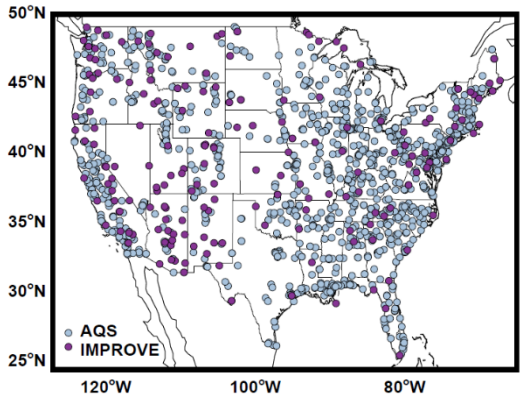
+ Canadian and Washington Fires Summer 2015

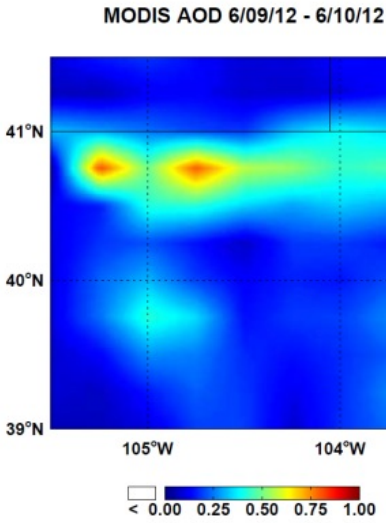
We have three imperfect tools to determine smoke concentrations

In-situ monitors (AQS, IMPROVE)

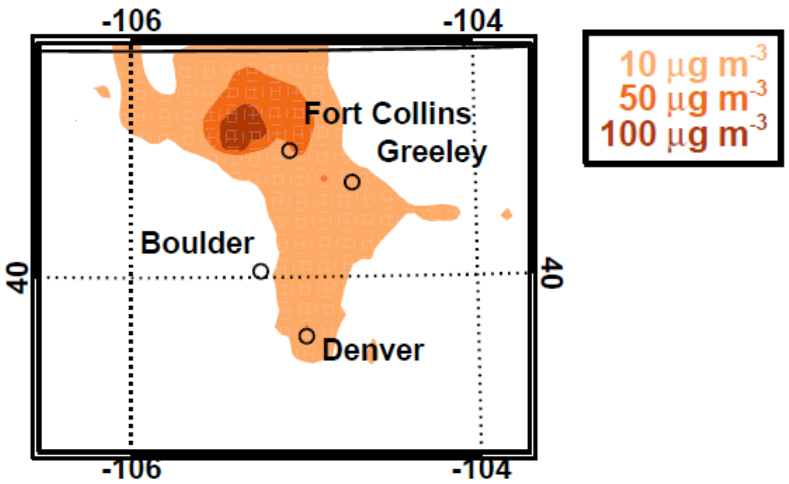




Satellite observations (MODIS, MISR, GOES)

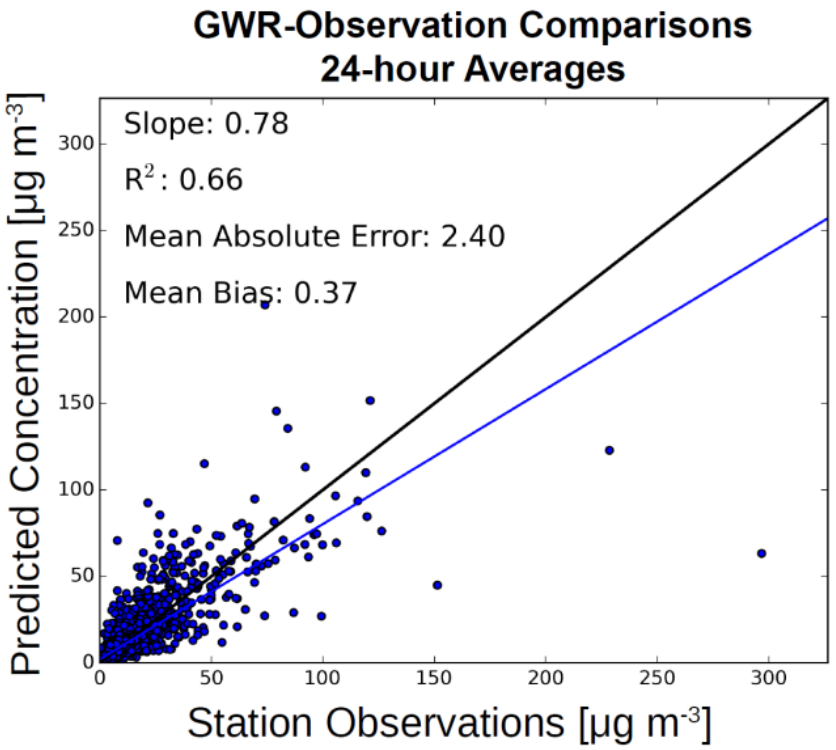


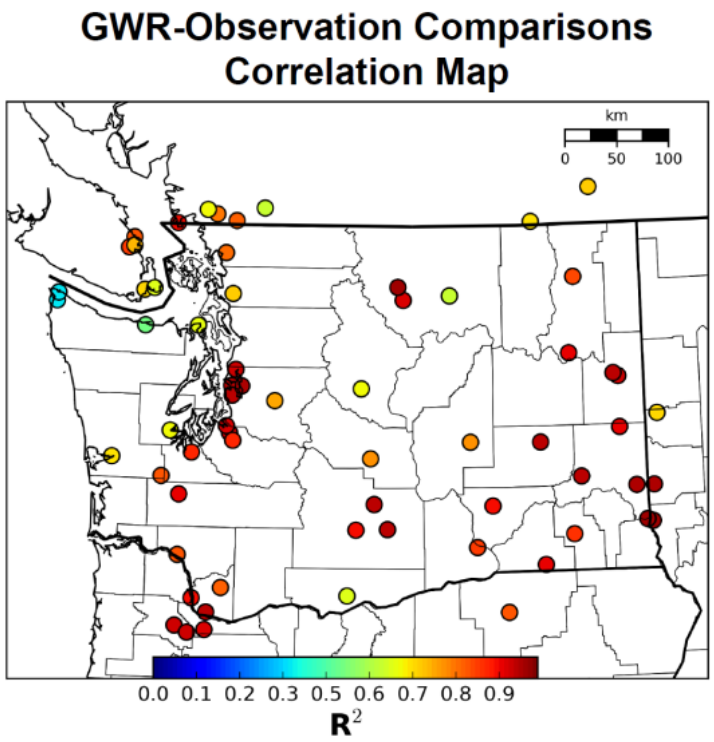
Chemical Transport Model (WRF-Chem)



We combine information using Geographically Weighed Regression

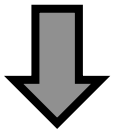
$$PM_{est} = A + B * PM_{krige} + C * PM_{wrf} + D * AOD_{MODIS}$$





Method to Assess Relationship Between Wildfire Smoke and Health Outcome

Blended wildfire smoke $PM_{2.5}$ concentrations



Join smoke estimates to hospital claims data

Assess relationship using case-crossover study design

Health Outcomes

Hospital claims data from the **Washington State Comprehensive Hospital Abstract Reporting System** (CHARS) for the year of 2012

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Primary diagnosis of cardiopulmonary health outcomes using ICD-9 codes and restricted to an emergency or urgent care visit

- Asthma (e.g. ICD-9 codes 493.00 to 493.92)
- Chronic Obstructive Pulmonary Disease (COPD) Exacerbations
- Pneumonia or Bronchitis
- Arrhythmia
- Cerebrovascular Disease
- Heart Failure
- Myocardial Infarction

WRF-Chem and Geo-weighted method show increased risk for asthma hospital visit as wildfire smoke increases

	WRF-Chem 10 μg m^{-3} increase		**Geo-weighted 10 μg m^{-3} increase**	
Health Outcome	Odds Ratio	95% CI	Odds Ratio	95% CI
Asthma	**1.11**	**1.07 – 1.15**	**1.10**	**1.05 – 1.16**

WRF-Chem shows decreased risk and Geo-weighted shows increased risk

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Asthma	1.11	1.07 – 1.15	1.10	1.05 – 1.16
COPD Exacerbation	**0.98**	**0.93 – 1.04**	**1.11**	**1.05 – 1.17**

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Asthma	1.11	1.07 – 1.15	1.10	1.05 – 1.16
COPD Exacerbation	0.98	0.93 – 1.04	1.11	1.05 – 1.17
Pneumonia	**0.98**	**0.94 – 1.03**	**1.06**	**1.00 – 1.11**

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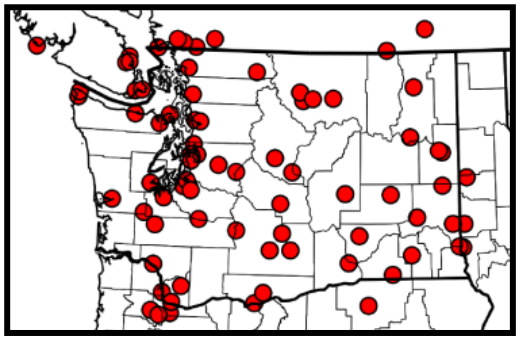
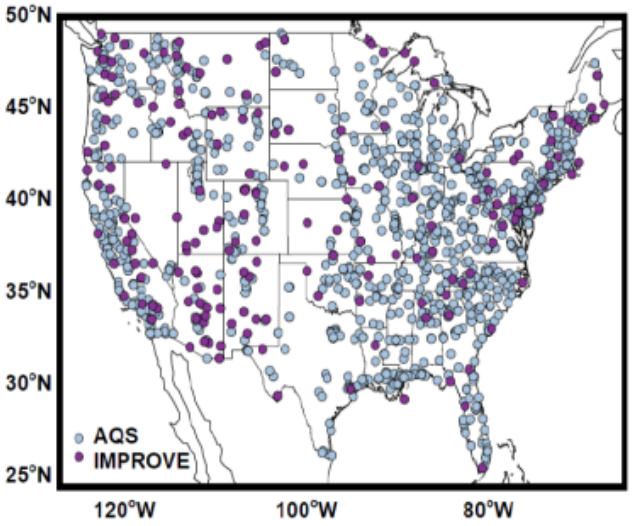
COPD Exacerbation	0.98	0.93 – 1.04	1.11	1.05 – 1.17
Pneumonia	0.98	0.94 – 1.03	1.06	1.00 – 1.11

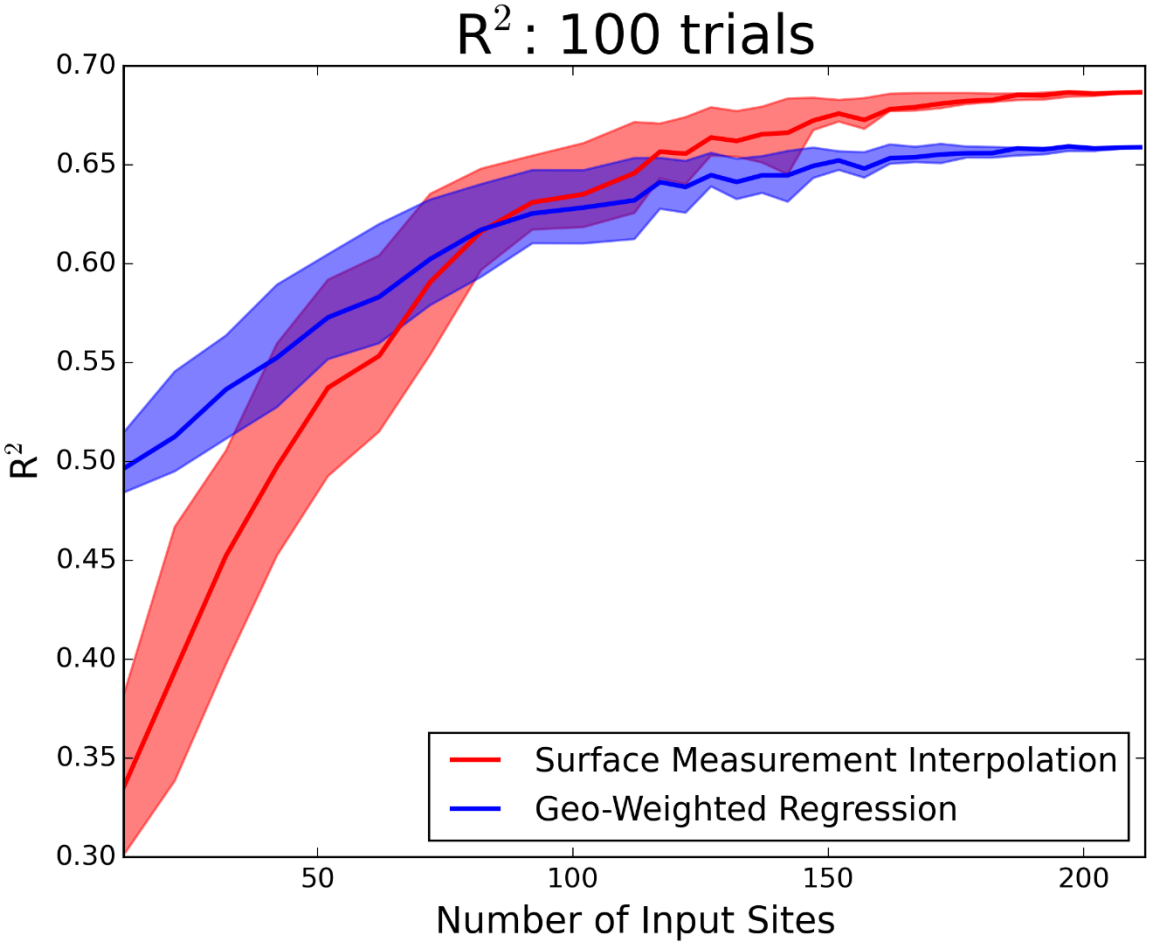
With CDC (Rish Vaidyanathan):

Mortality response to acute smoke exposure using National Vital Statistics data

Blended estimates are important for regions with few surface monitors





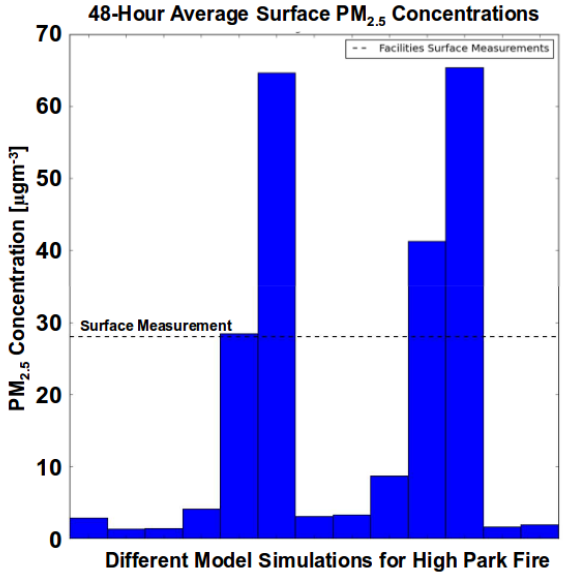


**part of William Lassman's MS Defense, successfully defended on 8 September 2016*

Objective 2: Forecast Evaluation and Development

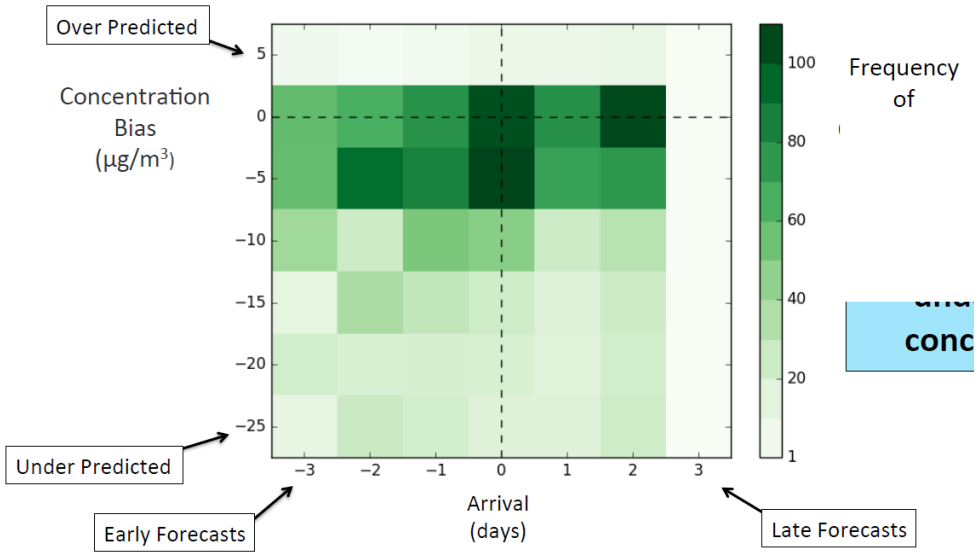
WRF-Chem

- Analyzed multiple fires
- Sensitivity tests for High Park Fire June 2012
  - **Resolution**
  - **Meteorology fields**
  - **Biomass Burning Inventory**
  - **BB emissions timing**
  - **Sub-Grid Parameterizations**

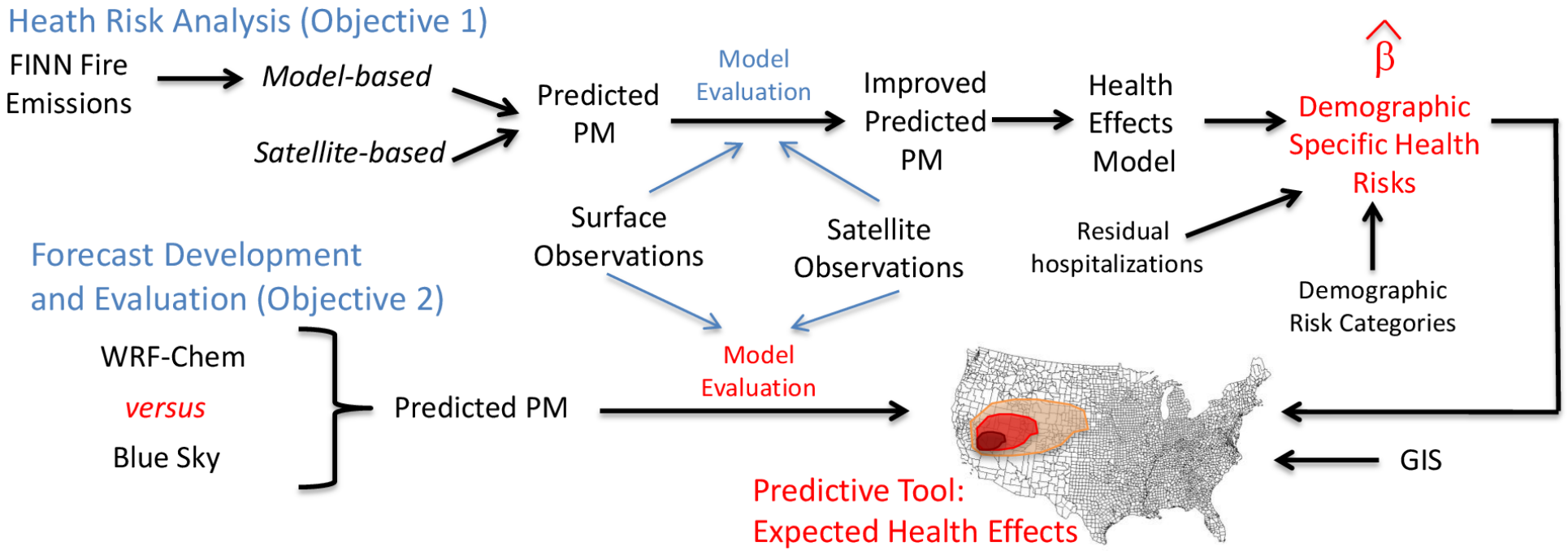


Bluesky Framework

•Compared forecasts to surface measurements for summer 2015



Forecast tool



CDC Smoke-Health forecast tool
Rish Vaidyanathan

Goals for upcoming year

- Publish papers on Washington 2012:
  - Part 1: smoke-exposure estimates (Will Lassman)
  - Part 2: health effects (Ryan Gan)
- Repeat Analysis for Washington 2015, Oregon 2013/2015
- Continue testing smoke-forecast models
- Integrate results with CDC

Risks to schedule

- Turnover time: Graduating MS student and new MS student
- Delays in obtaining health and in situ data for summer 2015
- More research questions than staff!

Budget Status

	Budgeted through Year 2	Actual To Date 08/31/2016	Projected through 01/31/2017	Unencumbered through Year 2
Total Costs	767,264.00	438,239.61	573,851.05	193,412.95

- Under budget on project mainly due to previous year

ARL Review

Starting ARL: **2**

Current ARL: **4**

Projected Ending: **8**

ARL 4 –Initial Integration & Verification

Components of eventual application system have been brought together and technical integration issues have been worked out: We finalized our exposure estimate techniques and calculated the odds ratio of asthma, all respiratory, COPD, and pneumonia/bronchitis hospitalizations associated with exposure to wildfire smoke using these concentration estimates for one wildfire event. There were some difficulties in merging the concentration estimates with the health and population data, but these issues have been overcome, and we have standardized our process. This has sped up our process and we are now repeating this process for several more fires.

Organizational challenges and human process issues have been identified and managed. Our project is fully staffed at CSU, and we now have named liaisons at each of our stakeholder organizations (CDPHE, Dept. of Ecology, and CDC) with clear partnership goals. These partnerships have been solidified by the transfer of actual data.

Detailed Budget Status

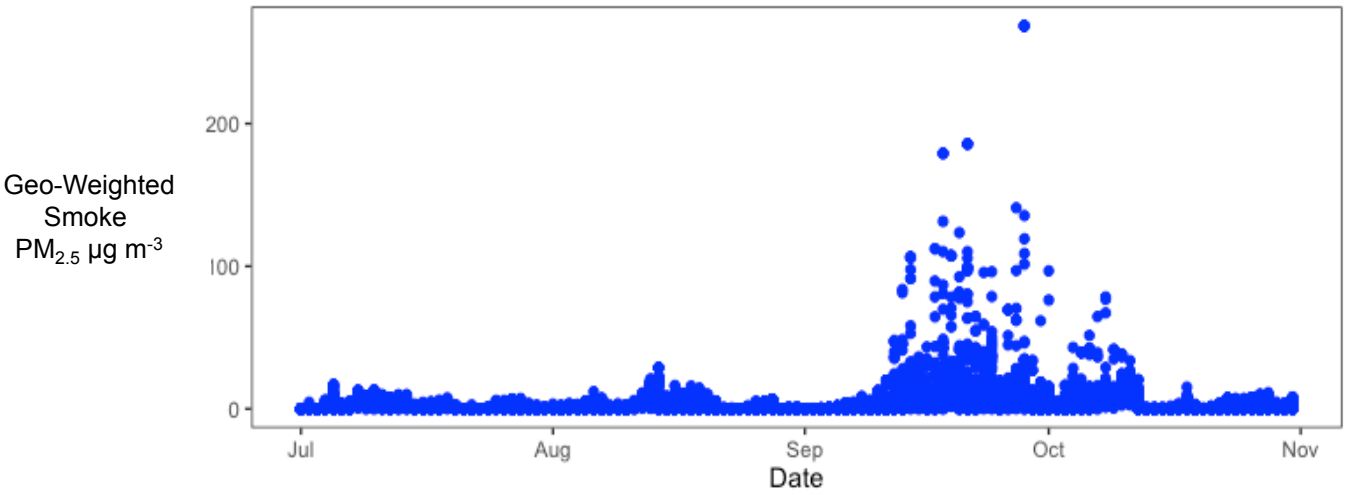
	Budgeted for Year 2	Actual To Date 08/31/2016	Projected Thru 01/31/2017	Unencumbered for Year 2
Total Salary	423,250.00	249,714.60	318,291.82	104,858.18
Travel	32,163.00	11,577.05	15,052.03	17,110.97
Supplies	4,000.00	5,984.65	5,984.65	-1,984.65
Other Direct				
Tuition	22,736.00	14,338.10	20,142.00	2,594.00
Publications	3,000.00	0.00	0.00	
Computer	2,103.00	1,013.04	1,313.04	789.96
Subcontract NCAR	41,767.00	16,782.20	35,000.00	6,767.00
Total Direct Costs	528,919.00	299,409.70	395,783.60	133,135.40
Indirect Costs	238,345.00	138,829.87	178,067.46	60,277.54
Total Costs	767,264.00	438,239.61	573,851.05	193,412.95

Descriptive Characteristics

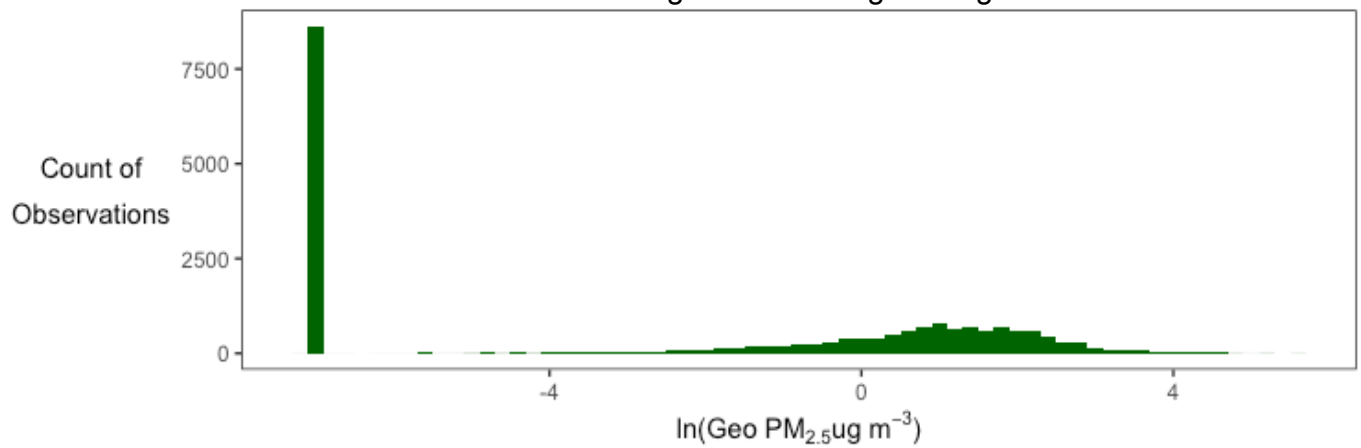
Outcomes from July through October were relatively rare, except pneumonia and bronchitis

Outcome	Events
Asthma	1,456
COPD Exacerbation	1,583
Pneumonia	3,165
Arrhythmia	3,238
Cerebrovascular Disease	4,208
Heart Failure	2,975
Myocardial Infarction	2,689

Geo-weighted smoke was highest in mid-September to start of October



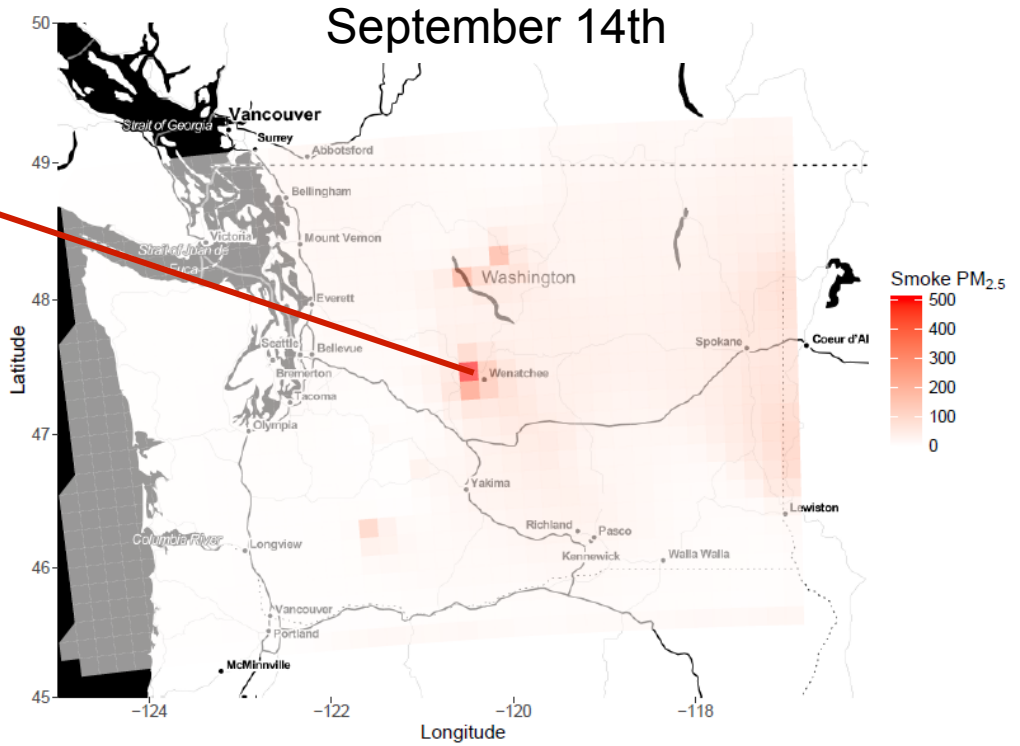
Left-skewed distribution of log-transformed geo-weighted smoke estimates



Identify all persons within the CHARS dataset with the outcomes of interest in the specified time frame

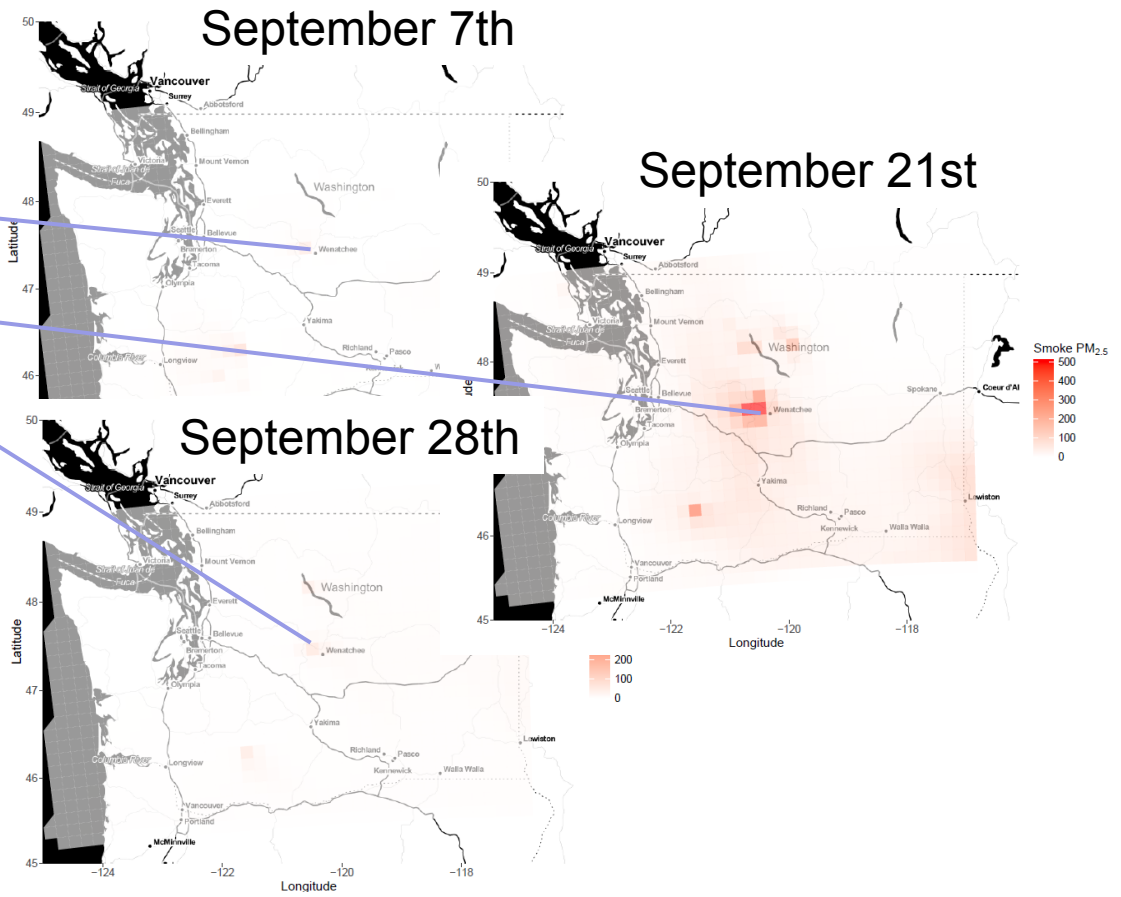
Join estimations of wildfire smoke to that person's record based on location and date

September 2012						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						



Create counterfactual observations when outcome did not occur and join wildfire smoke estimates

September 2012						
Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						



WRF-Chem and Geo-weighted methods lead to different conclusions for cardiovascular outcomes

	WRF-Chem 10 μg m^{-3} increase		**Geo-weighted 10 μg m^{-3} increase**	
Health Outcome	Odds Ratio	95% CI	Odds Ratio	95% CI
Arrhythmia	0.96	0.92 – 1.01	1.02	0.97 – 1.07
Cerebrovascular Disease	1.01	0.98 – 1.05	1.03	0.99 – 1.07
Heart Failure	0.97	0.93 – 1.02	1.05	0.99 – 1.10
Myocardial Infarction	0.98	0.93 – 1.03	1.05	0.99 – 1.11